# 60,000 VOLT STEEL TOWER LINE CONSTRUCTION

SOUTHERN CALIFORNIA EDISON COMPANY

HARRY W. DENNIS, C. E.

1914

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# SOUTHERN CALIFORNIA EDISON COMPANY.

By Harry W. Dennis, C. E.

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in the Class of 1899.

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E.V.

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# 60,000 VOLT STEEL TOWER LINE CONSTRUCTION OF SOUTHERN CALIFORNIA EDISON COMPANY.

## HISTORICAL:

In the Spring of 1912 construction was started on a steel tower transmission line for the transmission of electricity at the rated voltage of 60,000, connecting certain of the main stations of the Southern California Edison Co. This Company operates extensively in Southern California, and has a transmission system as shown on the accompanying map. A brief synopsis descriptive of the system of the Southern California Edison Company will show the reasons for the new tower line construction, and will be of assistance in following the description of the new work.

The transmission system interconnects all of the generating plants and substations and leads naturally to three primary centers of distribution, namely, Los Angeles, Colton and Santa Ana. The generating plants comprise both hydraulic and steam power, and include the following stations:-

| | | | | | |
|---|---|---|---|---|---|
| Kern River No. 1 | Hydraulic | Rated | at | 20,000 | K.W. |
| Santa Ana River No. 1 | " | " | " | 3,000 | " |
| " " " " 2 | " | " | " | 1,000 | " |
| Mill Creek No. 1 | " | " | " | 750 | " |
| " " " 2 & 3 | " | " | " | 3,250 | " |
| Lytle Creek | " | " | " | 500 | " |
| Redlands | Steam | " | " | 600 | " |
| Los Angeles No. 3 | " | " | " | 10,000 | " |
| Long Beach | " | " | " | 47,000 | " |
| TOTAL | | | | 86,100 | " |

The hydraulic stations, with the exception of Kern River No. 1, are relatively close to Redlands, and, taken with the Redlands Steam Plant, may be considered as one unit of the generating system with principal re-

OWENS LAKE
TULARE
KERN RIVER No 5
KERN RIVER No 4
KERN RIVER No 3
INYOKERN
KERN RIVER No 2
KERN RIVER No 1
BAKERSFIELD
CALIENTE
KERN
MOJAVE
TEJON
VENTURA
LOS ANGELES
SANTA BARBARA
PIRU
CASTAIC
ACTON
FILLMORE
SANTA PAULA
VENTURA
SATICOY
SAN FERNANDO
SAN BERNARDINO
LYTLE CREEK
OXNARD
HUENEME
VAN NUYS
MONROVIA
UNION POWER
S.A.R. #1
S.A.R. #2
PASADENA
CLAREMONT
COLTON
M.C. #2 & #3
SAWTELLE
LOS ANGELES
POMONA
REDLANDS
M.C. #1
SANTA CRUZ ISLAND
SANTA MONICA
WHITTIER
CHINO
RIVERSIDE
PACIFIC
INGLEWOOD
FULLERTON
RIVERSIDE
REDONDO
ORANGE
LONG BEACH
SAN PEDRO
SANTA ANA
OCEAN
ORANGE
Scale of Miles
0 5 10 15 20 25
Generating stations
Proposed " "
Sub stations

ceiving substation in the city of Colton. This "Colton group" is widely separated from the other generating stations and there is now steel tower line construction connecting the Colton substation with Los Angeles No. 3, Long Beach and Kern River. The transmission line between Kern River No. 1 and Los Angeles, a distance of approximately 118 miles, was built in 1907, and consists of a single line of steel towers carrying two circuits of 4/0 stranded copper cable supported on pin type insulators.

The original transmission line between Colton and Los Angeles was constructed in 1897, and consisted of two circuits of #1 copper wire supported by wooden poles. In the latter part of 1909 it became obvious that it would soon be necessary to arrange for replacing this wooden pole line, both because the wooden poles were rapidly giving out, and because the wire was too small for the requirements of the load which it was called upon to transmit. It is a matter of interest to note that this wooden pole line was constructed for the primary purpose of transmitting the hydraulic power of the "Colton group" of stations to Los Angeles for market, and that the load in the vicinity of Colton had reached such proportions that it not only required all of the capacity of the "Colton group" of stations, but it was necessary to transmit power from Los Angeles. The original line operated at 30,000 volts, and it was determined to plan the new line for 60,000 volts with long spans supported by steel towers and suspension insulators.

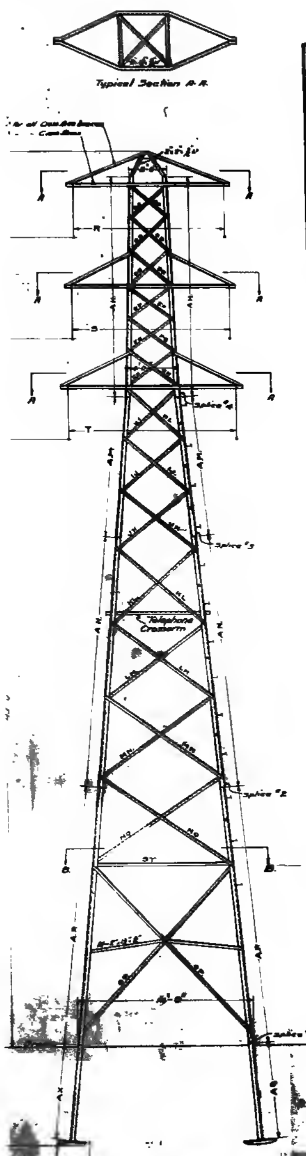
About this time, also, it became necessary for the Southern California Edison Company to provide for additional generating capacity, and the construction of the steam plant at Long Beach was started, unit No. 1 of this plant being put in operation in August 1911.

**TOWERS:**

The towers which were erected in 1907 for the Kern River line were intended for three circuits so arranged as to support five wires on the upper cross arm and four wires on the lower cross arm, the three wires of each circuit forming an equilateral triangle. For the new line a similar tower was designed. Competitive bids were secured, however, as a result of which a tower was chosen which would carry two circuits, for each of which the wires would be arranged in a plane nearly vertical, and would be supported at the ends of the cross arms. On account of right of way restrictions, it was determined that the towers would be made self-supporting without placing any reliance upon the use of side guys, and accordingly several sizes of towers were adopted, all, however, conforming to the same general design, the heavier towers being made up of heavier sections, and so designed as to provide for various range in angles. The standard tower was intended for use only on straight line work and deflection angles not exceeding one degree. There were eight special towers of the same height as the standard tower, but designed for angles so as to cover the whole range of deflection up to a full right angle. It also became necessary to have three other special towers conforming to the general design, but made higher to give the necessary clearance in certain special cases. Plate No. 1 herewith shows the design of these towers and the table shows the deflection angles, approximate weights and sizes of members.

The climatic conditions obtaining in Southern California made it unnecessary to consider any ice or sleet load upon the wires, and the controlling elements of the design, therefore, were -

(1) Range of temperature, from 20 degrees Fahr. to 110 degrees Fahr.

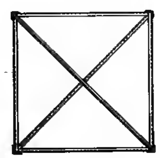



## SCHEDULE OF TOWER MEMBERS.

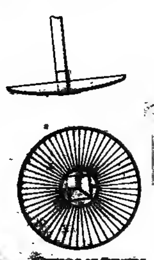
| TYPE | Deflec. Angle | Approx. Weight | AX | AP | AN | AM | AH | AS | No 1 | No 2 | No 3 | No 4 | No 5 | AC…UV (Index) | R | S | T | W | Z | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard | 0° to 1° | 4911 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | 6 | 4 | 4 | 4 | | [illegible] | 2-6" | 13-0" | 4-0" | 2-6" | 8-0" | |
| Special #1 | 1° to 6° | 4965 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | 6 | 6 | 4 | 4 | | [illegible] | 12-6 | 13-0 | 14-0 | 2-6" | 8-0" | |
| " #2 | 6° to 15° | 5101 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | 8 | 6 | 6 | 4 | | [illegible] | | | | 2-6 | | |
| " #3 | 15° to 25° | 5637 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | 6 | 6 | 6 | 4 | | [illegible] | | | | 2-6 | | |
| " #4 | 25° to 36° | 6267 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | 10 | 10 | 6 | 6 | | [illegible] | | | | 2-6 | | |
| " #5 | 36° to 47° | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | 12 | 10 | 8 | 6 | | [illegible] | | | | 2-6 | | |
| " #6 | 47° to 58° | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | 12 | 12 | 8 | 6 | | [illegible] | | | | 3-6 | | |
| " #7 | 58° to 65° | 7881 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | 14 | 12 | 10 | 6 | | [illegible] | | | | 3-6 | | [illegible] See note |
| " #8 | 65° to 90° | 8844 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | 16 | 14 | 10 | 6 | | [illegible] | | | | 3-6 | | |
| " #9 | 0° to 15° | 9901 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 6 | 6 | 6 | 4 | 8 | [illegible] | | | | 2-6 | | |
| " #10 | 0° to 1° | 6561 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 6 | 4 | 4 | 4 | 6 | [illegible] | | | | 2-6 | | |
| Dead End | [illegible] | 7881 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | 14 | 12 | 10 | 6 | | [illegible] | | | | 3-6 | | [illegible] Note |
| Special #11 | 1° to 8° | 7018 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 6 | 6 | 4 | 4 | 8 | [illegible] | | | | 2-6 | | |
| " #12 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | 8 | 6 | 6 | 4 | | [illegible] | | | | 3-6 | | [illegible] Note |

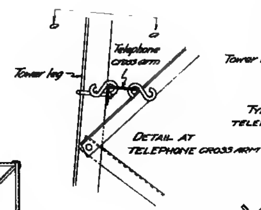
Note:
Standard Tower is Riter Conley Mfg Co.'s design, shown on their drawing #53814.
Special Towers are similar to above, except made heavier to stand increased loads.
For #8 Tower in earth, special reinforced concrete spread footing is necessary on tension side.
For Tower #45 between Anaheim Road and Newmark, first story spec. #11 was combined with spec #1 to make spec #11.

2-⅝" bolts, each end
3-⅝" bolts, each end

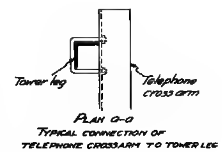


Section B-B.

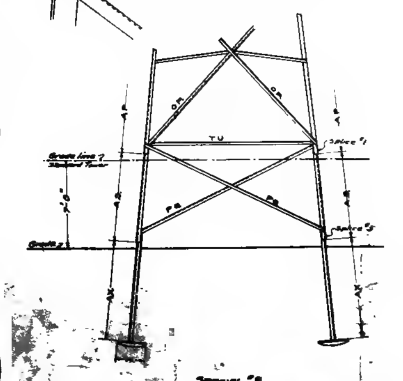




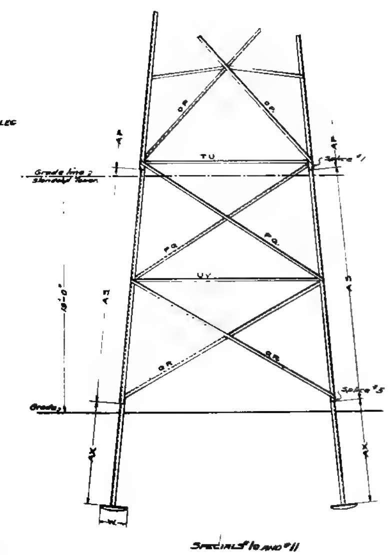

DETAIL AT TELEPHONE CROSSARM




PLAN O-O
TYPICAL CONNECTION OF TELEPHONE CROSSARM TO TOWER LEG




Special #2




Specials #10 and #11

| Los Angeles Sta #3 to Newmark | Newmark to Puente | Puente to Colton | Anaheim Road to Newmark | Ordered under Order #11952-0 May 14 '12 | Ordered under contract Dec. '11 | Ordered under contract Sept. '11 | Type |
|---|---|---|---|---|---|---|---|
| 18 | 70 | 152 | 117 | | 210 | 171 | Standard |
| | 12 | 37 | 13 | | 29 | 44 | Special #1 |
| 2 | 10 | 18 | 6 | | 26 | 14 | " #2 |
| | 2 | 6 | 6 | | 9 | 4 | " #3 |
| | | 6 | 1 | | 2 | 5 | " #4 |
| | 1 | | 2 | 1 | | 2 | " #5 |
| | | | 3 | | 3 | | " #6 |
| | | | | | | | " #7 |
| | | 2 | | | | 2 | " #8 |
| | | 6 | 4 | | 9 | 3 | " #9 |
| | | 1 | 1 | | 1 | 1 | " #10 |
| 1 | | 2 | 8 | 10 | | 1 | Dead End |
| | | 1 | 2 | 2 first story | 2 | | Special #11 |
| | | | | | 1 | | " #12 |

Southern California [illegible]
Long Beach to Colton Line
Transmission Towers

Revised
Revised
Revised

PLATE NO. 1.

(2) Wind, for which the possibility was considered of an actual velocity of 60 miles per hour occurring at 40 degrees Fahr.

(3) One broken wire.

(4) Maximum strain in stranded copper cable 22,000 pounds per square inch.

(5) Maximum tension in steel 30,000 pounds per square inch.

(6) Maximum compression for tower legs according to the following formula:

$$p = \frac{21500}{1 + \frac{l^2}{36{,}000\, r^2}}$$

in which p is allowable compression in pounds per square inch, l is unsupported length in inches and r is least radius of gyration in inches, the ratio $\frac{l}{r}$ being limited to 150.

(7) The holding down effect of earth at 45 pounds per cubic foot, including the weight of the frustum of a cone, the angle of whose sides with the vertical was 45 degrees, this latter requirement being equivalent to factor of safety of two with ninety pounds per cubic foot for actual weight of earth.

The towers were purchased from the Riter Conley Manufacturing Company under specification which required a shop load test. All members were required to be hot galvanized and all bolts to be sherardized. The height of the towers was determined by consideration of minimum clearance of 33 feet above the surface of the ground, and 8 feet between cables, and the tower locations were adopted in accordance with a standard spacing of 700 feet, the variation in this spacing being made where towers were located on ridges permitting ample sag, and the maximum spacing between any two towers as erected was 1874 feet. The line was located upon a private right of way for the entire dis-

tance of approximately 75 miles, with the exception of a distance of 1.94 miles upon the city streets of the city of Los Angeles, and although the tower as described was used for the major portion of the line, it was necessary to adopt for certain pieces of right of way a smaller structure.

For a distance of seven miles, the line is located in valuable ranch property, where it became necessary to construct a pole not more than three feet square, and this pole was erected, requiring a standard spacing of 660 feet.

In the city streets of Los Angeles still another design was made necessary, where the Company was required to provide 45 foot clearance under the line, and a maximum dimension of 18 inches square at the ground. For this part of the line most of the spans are about 200 feet.

Plates Nos. 2, 3 and 4 show completed structure of each of the foregoing types.

Reference to plate No. 1 shows that each footing of the towers consists of a single angle bolted to a dished plate 2 feet 6 inches in diameter, excepting for the special towers Nos. 6, 7,8 and 12, and dead end, for which the disc is 3 feet 6 inches diameter. Concrete was used in this footing only to provide uniform bearing under the discs, and at the crossings of railroads where the requirement was made that the angles should be encased in concrete up to the ground line, so as to prevent rusting. Although due consideration was given to the matter of preparing concrete foundations to a point above the ground line, the cost of same made it prohibitive, due largely to the fact that much of the line was built through desert country, where it would have been necessary to haul materials and water a long distance in order to prepare such concrete footings, and the Company's previous experience on the Kern River towers, where no concrete was used, had been such as to warrant the repetition of the same


PLATE NO. 2.

Standard tower. Base 14 feet square.


PLATE NO. 3.

Tower in Chino Ranch, Base 36 inches Square.

PLATE NO. 4.

Steel Pole in City of Los Angeles, Base 18 inches square.

kind of construction.

For the steel poles having base 36 inches square a spread concrete footing was prepared, although for the steel poles, whose base was 18 inches square, the character of the soil was such as to make a spread footing unnecessary, and the back fill only was made of concrete.

....

INSULATORS:

Suspension type insulators are used throughout on this transmission line, the type chosen being the Locke 10 inch insulator No. 2565. Although these insulators were purchased under specification which required successfully withstanding test of 90,000 volts, four units in series are used at all supporting points other than points where strain in the direction of the line occurs, at which points five units in series were installed. The wisdom of providing one extra unit at strain points is apparent when consideration is given to the difficulty involved in replacing one of these strain units, and by having the extra insulator one unit may fail electrically without causing a shut down of the line and the tedious operation of replacing the broken unit.

Dead end construction is used at all angle points where the deflection is more than 1 degree and the cable is placed, without splicing, in a loop so as to give a clearance of 30 inches from the tower structure. This type of construction is also adopted at crossings of steam railroads in accordance with the railroad companies' specification that the conductor should be dead ended at the tower on each side of the crossing span.

The railroad specifications also require that suitable grounding arm should be erected under the wires so that in the event of mechanical

failure of the insulator, the live transmission conductor would not fall upon the railroad tracks.

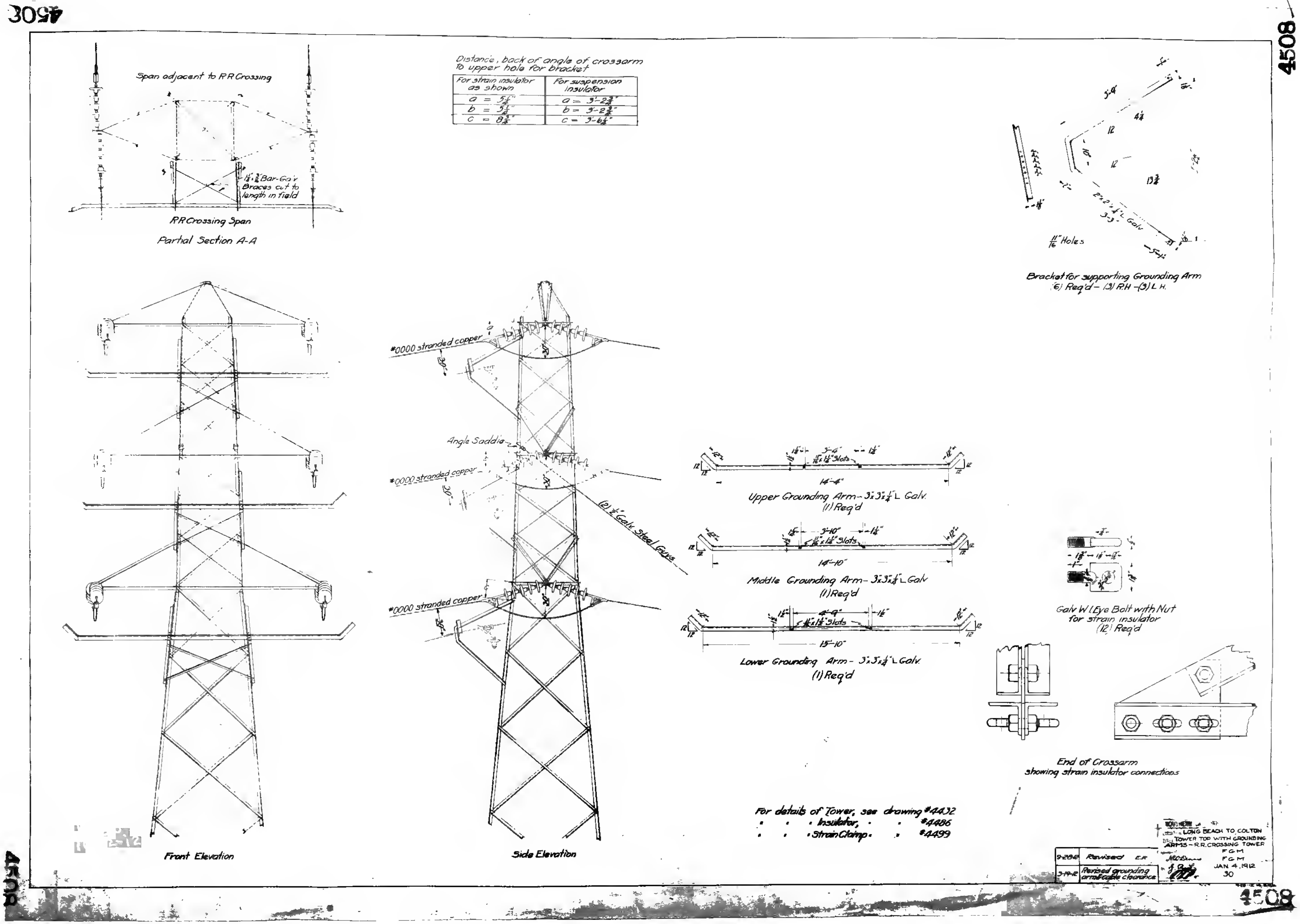
Plate No. 5 shows the grounding brackets and the method of dead end construction.

....

SETTING STUBS FOR TOWERS:

The setting of the stubs for the towers is one of the distinct operations carried on by a separate squad of men independent of the men who are engaged in the other operations incidental to the construction of the steel tower line. In order to accomplish this work satisfactorily the essential elements are securing proper back fill under and around the stubs, and in fact the filling of the entire hole up to the surface of the ground, and the assurance that when this back fill is complete the holes through which the tower legs are secured to the stubs will be at proper elevation and location to conform to the shape of the base of the assembled tower. In the first towers which were erected on the lines here described, there was a considerable amount of time lost due to the failure to secure these objects and as a result of subsequent experience, the following procedure was adopted:

It being apparent that the original soil would be disturbed at least for a short distance under the stubs, and that difficulty would exist in securing compact back fill of earth under the discs, concrete was used for the back fill under the anchor plates. This concrete was in general carried only up to the top of the anchor plate, and the remainder of the hole was filled with excavated material. At angle towers, however, the entire hole for about 18 inches above the disc was filled with concrete, the bottom of the hole having been enlarged so that it would be impossible for the ten-



4508
Span adjacent to R.R. Crossing
R.R. Crossing Span
Partial Section A-A
Distance, back of angle of crossarm to upper hole for bracket
For strain insulator as shown
For suspension insulator
Front Elevation
Side Elevation
Angle Saddle
#0000 stranded copper
(2) ½" Galv. Steel Guys
Upper Grounding Arm - 3" x 3" x ¼" L Galv.
(1) Req'd
Middle Grounding Arm - 3" x 3" x ¼" L Galv.
(1) Req'd
Lower Grounding Arm - 3" x 3" x ¼" L Galv.
(1) Req'd
Bracket for supporting Grounding Arm
(6) Req'd - (3) R.H. - (3) L.H.
Galv. W.I. Eye Bolt with Nut for strain insulator
(12) Req'd
End of Crossarm
showing strain insulator connections
For details of Tower, see drawing #4432
" " Insulator, " " #4486
" " Strain Clamp, " " #4499
LONG BEACH TO COLTON
TOWER TOP WITH GROUNDING ARMS - R.R. CROSSING TOWER
F G M
F G M
JAN 4, 1912
30
9-28-12 Revised
3-19-12 Revised grounding arm & cable clearance
4508


PLATE NO. 5.

sion stubs to pull out except by lifting the adjacent earth. In order to secure the proper final position of the bolt holes, there was used a wooden templet in conjunction with nine stakes, one located at the center of the tower and two adjacent to each hole. The templet which was chosen consisted of a piece of 2 x 4 lumber, at one end of which was securely fastened a piece of 2 x 2 at the proper bevel, so that when the main member of the templet was horizontal and one end correctly located at the center of the tower, the other member of the templet was in a position to lie inside of the angle which formed the tower stub. The templet accordingly rested upon the center stake and one of the above mentioned stakes near the hole for the leg, which of course was so set as to give the proper direction for the templet relative to the tower base. The other stake to which reference has been made was located within 24 inches of the location of the stub, so as to be within reach of a carpenter's level, and with the combined use of the templet and this level the stub could be properly located to conform to the foregoing requirements. On certain side hill work it was necessary to do some trenching, so that the templet could be conveniently used, but the expense of such extra excavation was considered preferable to arranging for special tower members which would conform with the actual ground conditions.

On account of the improper setting of some of the tower stubs and the failure of the sub-foreman to appreciate the necessity for extreme accuracy, an experiment was made by using another type of templet upon which two stubs diagonally opposite one from the other could be suspended, in hopes that this method would secure the desired result without the extreme care made necessary by the method above described. In the construction work, however, it was

found that this templet was too long and bulky to be handled readily, and transported between towers, and that it lacked sufficient rigidity, to overcome which would have required that it be made heavier, and accordingly the original method was adopted for the remainder of the work.

ASSEMBLING OF TOWERS:

The assembling of the towers was carried on by a crew of eight men and a sub-foreman. Except in special cases, the towers were erected on the ground so that the vertical axis of the tower lay in the direction of the line. The tower material was spread out on the ground in the proper position, so that when the members forming the two sides were fully bolted together, they were then tipped up into vertical position and held while certain of the cross members of the other sides were securely fastened to the leg members. After the tower was fully assembled, all of the bolts were tightened, but the final tightening was deferred until after the tower was erected. In special cases it became necessary to assemble the tower in place where local conditions were such that a large amount of benching would have been required for assembling the tower on the ground, or where other conditions made the usual procedure impossible.

.....

ERECTION OF TOWERS:

The erection of the towers was accomplished by eight men and a foreman and one team, and the process is shown in the accompanying plate No. 6. A sling was fastened to the tower at the lower cross-arm and carried over a gin pole to a set of blocks, one end of which was in turn anchored to a dead man buried in the ground about 70 feet from the base of the gin pole. Fastened to the foot of the tower at the holes provided for the splice between

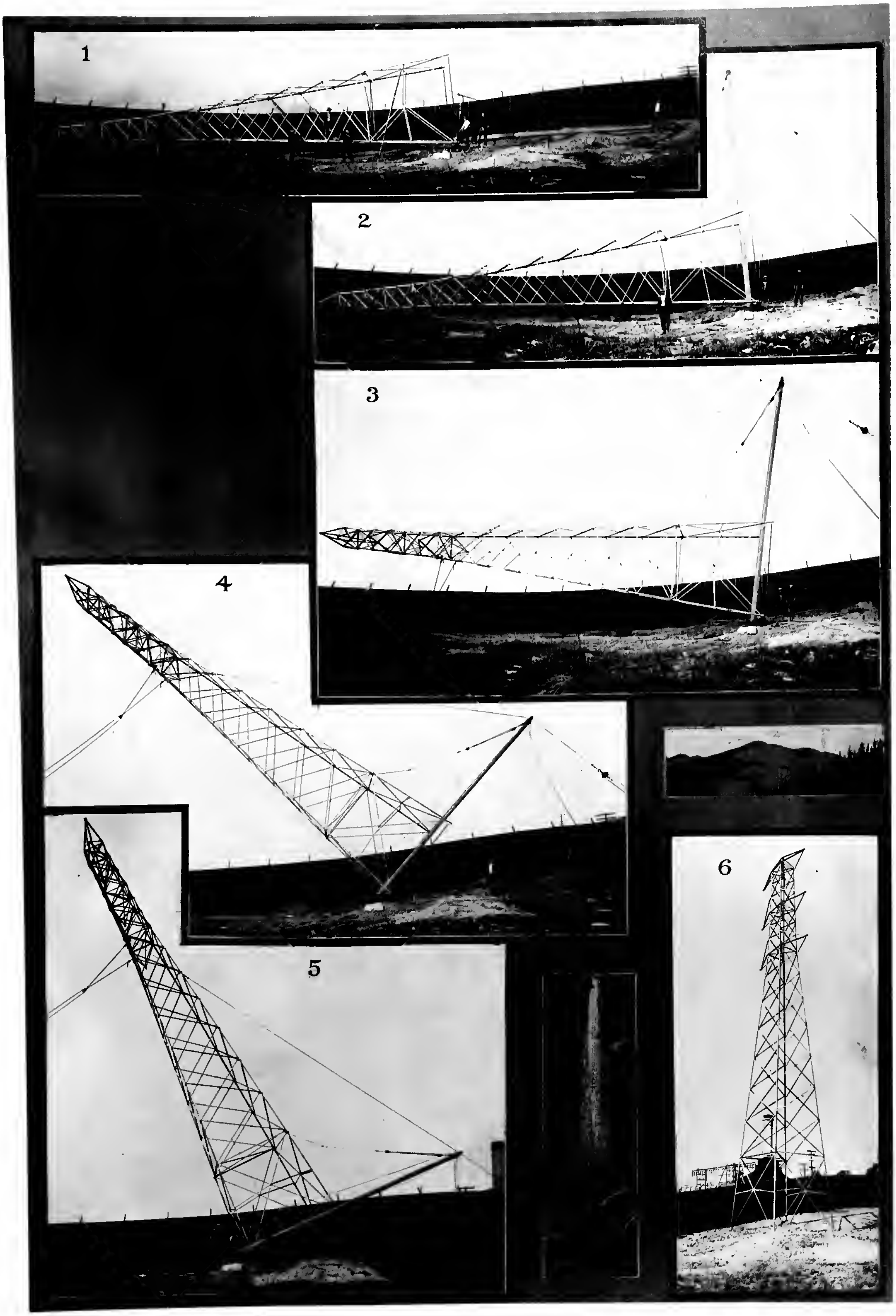



PLATE NO. 6.

tower legs and the stubs there was temporarily secured a 6 inch wrought iron pipe, each end of which was securely snubbed back by chains to three long steel pins driven in the ground. Temporary struts were used between the ends of adjacent tower legs. The pipe also served as a convenience in securing the lower end of the gin pole. Side guys for the gin pole were of course provided, these guys being snubbed to pins driven in the ground, care being taken that the guys were directly opposite and at right angles to the axis of the tower. No side guys were provided for the tower itself, inasmuch as the width of the base is approximately 14 feet and the pipe was securely supported at either end. A back guy for the tower was provided, however. Plate No. 6 shows that the gin pole is at all times at right angles to the axis of the tower, so that when the tower reaches the vertical position, the gin pole is upon the ground. Under either end of the pipe planks are provided so that the tower may be conveniently pinched in any direction to bring the holes in the legs of the tower fair with the holes in the stubs, and after two of the legs are bolted an additional strain is taken in the hoisting line, so that the legs carrying the pipe are somewhat elevated, and the pipe itself is removed, whereupon the tower is slacked back and the two other connections are made. Although the actual operation of raising the tower from the time the upper cross arm left the ground until the tower stood in a vertical position was accomplished in a very short time, the actual time involved in the operations of digging hole for dead man, arranging slings and pipe, placing gin pole, hoisting line and back guys, bolting tower legs to stubs, assembling and loading equipment and transporting same to the next tower, there to repeat the operation, consumed something over an hour. The best day's work accomplished by the tower erecting crew consisted in the complete erection of ten towers in an eight hour working day.

After the towers were fully erected and before any strain was brought upon them by stringing wire, a separate crew of men tightened all of the bolts so as to develop as much pressure as possible between adjacent tower members, and in order to prevent a subsequent loosening of the bolts by vibration or other agencies, each bolt was "center punched" so as to injure the thread both of the bolt and the nut.

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PREPARATIONS FOR STRINGING WIRE:

The wire used on this transmission line was 4/0 copper cable having seven strands. It was furnished in reels having total weight of approximately 2000 pounds, this being in nominal lengths of one half mile per reel, and was delivered to the Company at various convenient railroad sidings, from which points it was distributed along the line. For unreeling the wire the method first used involved a heavy wagon having specially constructed frame work with provision for hoisting three reels and slinging same on steel rollers through the centers of the reels, the end of each wire being spliced to the wire already strung out. The wagon was then taken along the line unreeling the wire between the towers. This method was possible because all of the wires were supported at points outside of the frame of the tower, but was subsequently abandoned on account of the facts -(1) that in various locations the ground was so rough that hauling the wire in this way was impracticable; (2) that part of the towers were erected parallel to property fences, so that there was insufficient room to haul the wagon between these fences and the towers; (3) and that it became necessary to take down whatever fences were crossed by the line, so as to allow the wagon to pull through.

The principal advantage in this method of unreeling the wire lies in

the fact that the wire was not dragged over the ground, although it must be borne in mind that where the ground conditions were such as to harm the wire it was in general so rough as to make it impossible to use this method at all. The method finally adopted as being more flexible and suitable for all occasions was by supporting the reels on standards and dragging one or more wires into position.

As has already been described, the insulators were 10 inches in diameter, No. 2565 manufactured by the Locke Insulator Co. These insulators were purchased subject to test and acceptance at the Company's test department at Los Angeles, and there being no means of testing these units after leaving the Company's warehouse, special precautions were adopted so as to transport them safely from the warehouse to the site of the work. This transportation was accomplished by means of automobile truck, and special crates were built so as to eliminate as far as possible any accident to the insulators after leaving the test. For the standard towers there were required four for each point of support, a total of 24 units. These crates were built accordingly, each crate providing for three strings of four units each to be supported top and bottom, and to be clear so that the porcelain would not be in contact with any part of the crate. It was the intention to leave these insulators in the crates until the linemen could swing them into position on the towers, but for certain reasons the method was given up and the insulators, after being tested, were again packed in the original crates for shipment to the work, it having been found that irregularity in construction progress coupled with the extremely long haul, in some instances nearly 60 miles, made it impossible to supply the insulators in proper time for construction, and that the method of supporting the insulators in the new crates subjected them

to severe mechanical strain, involving in many instances loosening of the hardware of the insulator units.

To hang the wire to the insulators involved the use of the ordinary suspension type hardware with a malleable iron clevis furnished with the insulators, but to hang the insulators from the cross arms there was used a forged clevis having opening corresponding to the combined thickness of gusset plate and down standing legs of the tower cross arms. By this means a universal joint was secured so that any string of insulators might move in a direction either longitudinal or transverse with the line. For the dead-end construction used at all angles where the deflection was more than 1 degree, and at railroad crossings, there was used the dead-end hardware Locke No. 2383, together with a string of five insulator units fastened by means of a forged clevis to an eye bolt carried through a hole in the down standing legs of the tower cross-arm.

After the insulators with their hardware were hung in their proper position on the tower, the wire was strung through snatch blocks hung by chains as nearly as possible at the proper elevation, so that no further lifting of the wire would be required when proper tension had been secured, and everything was in readiness to transfer the wire into the insulators.

...

PULLING THE WIRE TO TENSION:

Although there were numerous angles in the right of way for the line here described, practical conditions made it impossible to pull to tension at one operation even on straight line work more than seven spans of wire representing a distance of approximately 4900 feet, it being found by experiment that even with this number of spans there was sufficient loss in

tension at each snatch block support to give a very large difference in sag in the first span as compared with the last. Accordingly the center span was observed in determining the proper sag for any one pull. The major part of the slack was pulled by use of a team and a final adjustment made by use of blocks. A special come-a-long was adopted consisting of two pieces of wrought iron in which suitable size groove had been machined. To one of these was forged an eye of ample size and the two pieces were bolted together over the wire by the use of four cap screws. The length of the bearing secured upon the wire was approximately six inches, which was found to be ample to develop sufficient friction for making the required pull without slipping or injuring the wire. The grooves in this come-a-long were rounded on all edges and the cap screws were of such size that the heads would fit the flat wrenches carried by the line-men for making up the insulator hardware, thereby reducing to a minimum the necessary tools required for the working outfit.

Although the proper tension in the wire was for a time determined by the use of dynamometers, this method was subsequently abandoned in favor of the sag method and the curves representing the proper sag for various conditions of temperature and span were for convenience on the part of the inspectors reduced to the following table:

## TABLE OF PROPER SAG DEPENDENT UPON TEMPERATURE AND SPAN

**4/0 COPPER CABLE.   MAXIMUM WORKING STRESS 22,000 POUNDS PER SQUARE INCH.**

Controlling conditions 20° Fahr. and no wind, or 40° and 60 mile wind.

| SPAN | 20° F. | | 40° F. | | 60° F. | | 80° F. | | 100° F. | | 120° F. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sag. | Stress. | Sag. | Stress. | Sag. | Stress. | Sag. | Stress. | Sag. | Stress. | Sag. | Stress. |
| 200 | 0.85 | 3655 | 1.0 | 3185 | 1.15 | 2740 | 1.37 | 2325 | 1.65 | 1960 | 1.95 | 1650 |
| 250 | 1.35 | 3655 | 1.6 | 3215 | 1.8 | 2795 | 2.1 | 2410 | 2.44 | 2075 | 2.8 | 1770 |
| 300 | 1.97 | 3655 | 2.25 | 3245 | 2.55 | 2850 | 2.93 | 2490 | 3.33 | 2185 | 3.77 | 1925 |
| 350 | 2.7 | 3655 | 3.03 | 3270 | 3.4 | 2900 | 3.85 | 2565 | 4.3 | 2285 | 4.83 | 2050 |
| 400 | 3.55 | 3655 | 3.95 | 3295 | 4.35 | 2950 | 4.85 | 2640 | 5.42 | 2380 | 6.97 | 2160 |
| 450 | 4.47 | 3655 | 4.93 | 3315 | 5.47 | 2990 | 6.0 | 2710 | 6.6 | 2465 | 7.23 | 2260 |
| 500 | 5.52 | 3655 | 6.05 | 3335 | 6.65 | 3035 | 7.25 | 2770 | 7.9 | 2545 | 8.56 | 2350 |
| 550 | 6.7 | 3655 | 7.27 | 3350 | 7.95 | 3070 | 8.6 | 2830 | 9.3 | 2620 | 10.0 | 2430 |
| 600 | 7.95 | 3655 | 8.62 | 3365 | 9.35 | 3110 | 10.05 | 2890 | 10.8 | 2690 | 11.55 | 2510 |
| 650 | 9.35 | 3635 | 10.1 | 3370 | 10.8 | 3135 | 11.6 | 2920 | 12.4 | 2740 | 13.2 | 2575 |
| 700 | 11.05 | 3580 | 11.85 | 3335 | 12.65 | 3120 | 13.45 | 2930 | 14.3 | 2765 | 15.15 | 2610 |
| 750 | 12.8 | 3535 | 13.65 | 3310 | 14.55 | 3120 | 15.4 | 2940 | 16.25 | 2785 | 17.1 | 2645 |
| 800 | 14.75 | 3500 | 15.65 | 3295 | 16.65 | 3115 | 17.5 | 2950 | 18.45 | 2810 | 19.25 | 2680 |
| 850 | 16.75 | 3465 | 17.7 | 3260 | 18.7 | 3115 | 19.6 | 2965 | 20.5 | 2830 | 21.5 | 2710 |
| 900 | 18.95 | 3440 | 19.95 | 3270 | 20.95 | 3115 | 21.95 | 2975 | 22.9 | 2850 | 23.85 | 2735 |
| 950 | 21.25 | 3415 | 22.25 | 3255 | 23.25 | 3110 | 24.30 | 2990 | 25.3 | 2865 | 26.3 | 2760 |
| 1000 | 23.8 | 3395 | 24.85 | 3240 | 25.9 | 3110 | 26.9 | 3000 | 27.95 | 2885 | 28.95 | 2785 |
| 1050 | 26.3 | 3375 | 27.45 | 3230 | 28.5 | 3110 | 29.55 | 3010 | 30.6 | 2900 | 31.65 | 2810 |
| 1100 | 29.05 | 3355 | 30.15 | 3220 | 31.25 | 3110 | 32.25 | 3020 | 33.4 | 2915 | 34.5 | 2830 |
| 1150 | 31.9 | 3340 | 33.05 | 3215 | 34.2 | 3110 | 35.3 | 3025 | 36.4 | 2930 | 37.5 | 2845 |
| 1200 | 34.95 | 3325 | 36.1 | 3210 | 37.25 | 3110 | 38.35 | 3030 | 39.5 | 2940 | 40.6 | 2860 |
| 1300 | 41.2 | 3310 | 42.3 | 3210 | 43.5 | 3120 | 44.7 | 3050 | 45.8 | 2960 | 46.9 | 2900 |

In connection with the use of the foregoing table the temperature as noted must be the temperature in the air on account of the variation due to even slight elevations above the ground. This is emphasized by a set of observations taken as follows:

Time - 10:40 A. M.
Location - Long Beach line about three miles from the ocean.
Temperature at elevation 45 feet above the ground - 75 degrees Fahr.
Temperature 4 feet above the ground - 80 degrees Fahr.
Temperature with thermometer lying on ground (clean dry sand)-116 degrees Fahr.
Temperature with thermometer lying on ground with bulb covered with sand - 127 degrees Fahr.

Where straight line occurred for more than seven spans, temporary dead-end connection was made by carrying the cables to the basket of the tower and securing the same by use of chains and come-a-longs, and when the proper tension had been taken in the spans ahead the strain in the chains would be relieved, and they could readily be removed and the wire transferred into the suspension hardware. On account of the fact that the standard towers were designed for the unbalanced pull of only one wire, and the further fact that even with this unbalanced pull there was a slight deflection of the tower, head guys were used to take up the strain, and whenever on angle towers the strain was finally imposed, the wires on opposite ends of the same cross-arm were slacked off simultaneously so as to avoid any possible twist in the tower. Wherever permanent dead-end construction was used, the cable of course was pulled past the tower, and after having been made up, the wire ahead was pulled back by the use of blocks so as to give the requisite loop under the dead-end insulators. By this method no splicing was required.

In the operation of making up the dead-end clamp in proper position a gage was used corresponding in length to the combined lengths of clevis,

insulators and dead-end shoe, thereby assuring the proper location of the dead-end clamp. The wire then was pulled above tension a sufficient amount to allow for the slack in the insulator units, this being required due to the weight of the insulators and the necessarily awkward position which the lineman must adopt in holding the insulator. The shoe being made up and the insulators placed, the wire was slacked off by hand, the necessary amount of wire in the loop measured and the opposite shoe located and hung to the cross-arm, whereupon the wire in the next span was pulled as before.

In certain special cases it became necessary to make a splice in the loop at the tower and in all these instances the strands were separated and interlocked with the strands of the other section and fully served out.

As has been mentioned, dead-end construction was required by the specifications of the railroad lines where transmission line crossings were made necessary, and the tower itself was required to be self-supporting under conditions of broken wires on spans adjacent to the railroad. At certain of these crossings dead-end towers were used and at other crossings standard towers with back guys, this latter construction having been chosen wherever right of way restrictions did not prohibit the use of such guys. At one of these crossings, where a short span was made necessary, it was found that the deflection of the towers was such that the tension in the crossing span exceeded that in the adjacent spans due to the tension of the back guys. On account of change in temperature, the tension developed in this short span became sufficient to mechanically rupture one of the strain insulators, and as a remedy for this condition the following construction was adopted:

Guy cables were strung between the baskets of the towers on opposite sides of the railroad and drawn to such tension as to take all of the strain

of the opposing back guys, and in addition thereto some of the strain of the transmission wires in the adjacent spans, whereupon the tension in the crossing span was reduced to such a point as to eliminate the possibility of further trouble.

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TELEPHONE SYSTEM:

The Southern California Edison Company, in line with the practice of most operating companies, has its own private telephone line interconnecting all of the generating stations and the principal substations. Although the telephone line is primarily intended for use in operating the system, for which use it would fulfill its purpose in any location, it must be borne in mind that there are long stretches of the transmission line here described which are not adjacent to any public highway, and accordingly it was decided to erect the telephone upon the same towers with the transmission line, so that the patrolmen could readily report the location of trouble, and likewise report clearance promptly after the trouble had been remedied. In general, one telephone pole is used in each span, it being the intention to limit the length of telephone span to 350 feet. There are many spans, however, wherein it was impracticable to locate this intermediate pole, and the telephone wire was obliged to make the same span as the transmission cables. The wire adopted for the telephone system was #6 B. & S. gage Phono-electric wire, and in order to minimize the induction on the line a telephone transposition was made at every tower. Dead-end construction was adopted for the towers, using Thomas suspension insulator No. 1074, having petticoat 4 inches in diameter. A worm's eye view of one of the telephone cross-arms is shown on accompanying plate No. 7.

PLATE NO. 7.

The insulator is secured to the steel cross-arm by the use of an "S" hook; the Phono-electric wire is made up by use of a special two-bolt cast iron clamp, a thimble being used where the wire hooks to the insulator; weather proof wire is used for the transposition; and the joint between the Phono-electric wire and the weather proof copper wire is soldered. The plate shows the construction as adopted on one of the steel poles, but the same details were followed on the towers, a single cross-arm being used on straight line towers and slight deflection angles, and two cross-arms, one on either face of the tower, used where angles were so great as to cause interference with the cross bracing of the tower. For that part of the line between Los Angeles No. 3 station and Newmark substation, there are three telephone circuits; between Newmark substation and Colton substation there are two; and between Newmark substation and Long Beach Steam Plant there is one circuit.

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The officers of the Southern California Edison Company for whom the work here described was carried out, are John B. Miller, President, W. A. Brackenridge, Vice-President and General Manager, and R. H. Ballard, Secretary and Assistant General Manager. The work was done under the personal supervision of the writer as Construction Engineer for the above Company.